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(54) **Means for parking read/write heads in a disc drive using the back-emf of the spindle motor to operate a stepper motor.**

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FR-A- 2 528 213
US-A- 3 518 651
US-A- 3 629 679

PATENT ABSTRACTS OF JAPAN vol. 10, no. 290 (P-503)(2346) 2 October 1986, & JP-A-61 107582 (TOSHIBA CORPORATION) 26 May 1986,

PATENT ABSTRACTS OF JAPAN vol. 7, no. 127 (P-201)(1272) 3 June 1983, & JP-A-58 45670 (MATSUSHITA DENKI SANGYO K.K.) 16 March 1983,

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EP 0 224 378 B1

Description

This invention relates generally to a disc drive for positioning a transducer array relative to discs and more particularly to an apparatus for parking the transducer array in a defined landing area relative to the surface of a disc when power is removed from the disc drive.

This invention is intended to provide a new and useful circuit for parking the read/write transducer in a disc storage apparatus utilizing a stepper motor actuator. Such a circuit is particularly useful in a magnetic memory storage apparatus of the type known as a Winchester magnetic disc memory storage apparatus. In disc drives of this type, an actuator is typically provided, situated adjacent the peripheries of several vertically spaced discs. The actuator is designed to rapidly position the transducers to access recorded disc information.

The transducers normally comprise floating read/write heads that fly on an air bearing over the surface of the disc. It should be noted that although this invention is described as used in a Winchester disc drive unit, and with a particular type of stepper motor for that unit, it will be appreciated that the invention is useful in other types of disc drives and electromechanical storage apparatus. The invention may also be useful in optical memory storage apparatus wherein one or several optical transducers are incorporated in the actuator, provided that it is desirable to park the heads in a defined position whenever the drive power source is removed.

In Winchester disc drives, it is desirable to park the read/write heads in a defined landing area on the surface of the disc to prevent possible damage to the recorded data. This landing area is typically at the inner area of the disc. This parking feature, along with mechanical latches, has long been provided on disc drives with voice coil actuators to prevent the read/write heads from moving across the recording media during power off conditions. Such movement, if allowed, could cause damage to both the heads and the discs and recorded data.

An advantage of the use of such a parking circuit for the transducer heads is that by moving the heads to the inside diameter of the disc, less torque is required to start the spindle motor when power is applied.

Many disc drives which use stepper motors to position the read/write heads on fixed media, Winchester type disc drives, do not automatically move the read/write heads to a landing zone when power is removed from the drive. Although a stepper motor has sufficient holding torque even when not powered to eliminate the need for a mechanical latch, the arguments for ensuring data integrity and reducing starting torque requirements still hold true in stepper motor actuator drives.

FR-A1-2528213 discloses a disc drive comprising one or more discs mounted for rotation within a disc drive housing, a spindle motor for driving the discs in rotation and an actuator for reciprocally driving a transducer array relative to the discs. The actuator includes a carriage for the transducer array and a motor drivingly connected to the carriage for positioning the carriage and the transducer array relative to the discs and a circuit for detecting removal of power. The disc drive also includes means for parking the transducer array at a defined park position relative to the discs including circuitry for disabling the normal motor control and a retract circuit coupled between the spindle motor and the windings of the actuator motor and reponsive to an output of said spindle motor to energise the windings of the actuator motor to move the transducer array to a defined position. EP-A2-0162614 discloses the use of stepper motors in disc drives.

This invention provides a disc drive comprising: at least one storage disc mounted for rotation within a disc drive housing; a spindle motor for driving said disc in rotation; an actuator for reciprocally driving a transducer array relative to the disc, said actuator including a carriage for said transducer array; a motor drivingly connected to the carriage for positioning the carriage and transducer array relative to the disc; and for detecting removal of power and for parking the transducer array at a defined park position relative to the disc after power is removed from the drive utilising power generated by the spindle motor, wherein: said carriage motor is a stepper motor, and said circuitry comprises a retract sequencer circuit including a power circuit coupled between the spindle motor and selected windings of the actuator stepper motor, and a clock circuit responsive to an output of a winding of the spindle motor, both power and clock circuits being activated by removal of power to the spindle motor to energise said selected windings of the stepper motor to step said stepper motor a number of steps necessary to park said transducer array at said defined position.

Thus, in accordance with the invention the momentum of the spindle motor is utilised to provide both a power source and a clock source for controlling the stepper motor of the transducer actuator. The circuitry is enabled only when power is removed from the disc drive and provides an economic arrangement for repositioning the read/write transducer heads in a landing zone located, for example, at the inner diameter of the discs to protect the recorded data on the discs.

The power generated by the spindle motor as it spins down is referred to as "back EMF". A sequencer circuit is provided to couple the power and clock pulses to selected windings of the step-

per motor in an order that will cause the stepper motor to rotate in the direction necessary to move the transducer heads to a predetermined park position at the inner diameter of the disc whenever power is removed from the disc drive. Since the location of the heads at power down may not be known, the timing of the pulses is such that a sufficient number of steps will be taken to move the transducer heads to the parking zone within the time allotted even if power down occurred when the heads were at the outermost track. Step pulses will continue to be generated until the back EMF of the spindle motor is insufficient to generate such pulses. After the transducer heads are at the predetermined parking location, any additional steps will cause the actuator to contact a mechanical "inner crash stop" designed to prevent damage to the transducer heads from contact with the clamp which retains the discs.

More specifically, when DC power to the disc drive is removed, an existing signal "DC UNSAFE" goes true. The negative going "DC UNSAFE" signal enables control circuitry to cause the stepper motor sequencer to drive the appropriate phases of the stepper motor and move the transducer heads to the landing zone. In the embodiment of the invention disclosed herein, only selected stepper motor phases are driven to perform the operation. The phases are driven in a unipolar manner by conventional transistors turned on and off by the sequencer circuit in response to a clock signal drived from the back EMF voltage of one spindle motor winding. By driving selected phases of the stepper motor, and using the spindle motor as both a power source and a clock source, the power down stepper retract circuitry of this invention economically positions the read/write heads in a landing zone which will protect the recorded data. This also reduces the starting torque requirements the spindle must provide when power is restored to the disc drive.

This invention can be best understood with reference to the following figures, wherein:

FIG 1 is a block diagram of the basic elements of electronic control circuitry present in a typical disc drive including the stepper motor and spindle motor and the circuitry which is added to implement this invention;

FIG 1B is a plan view of a known type of disc drive incorporating a stepper motor actuator which may utilize the circuitry of the present invention;

FIG 2 is a schematic of that portion of the circuitry of this invention which converts the analog back EMF signals from the spindle motor into digital signals;

FIG 3 is a schematic of the circuitry and logic elements of this invention which monitor the DC UNSAFE condition and sequentially enable the selected stepper motor phases;

FIG 4 is a schematic of the stepper motor driver circuitry of this invention; and

FIGs 5A and 5B are a holding torque vector diagram and timing diagram which are useful in understanding the function and advantages of the present invention.

Referring now particularly to the figures, wherein like elements are identified by like reference numerals, a disc drive utilizing the present invention is illustrated. Such a disc drive incorporates a spindle motor which drives one or more discs on a common spindle in constant rotation. A transducer is positioned relative to the disc under the control of a stepper motor as described in our EP-A-0162614A The essential elements of such a system are shown in FIG 1B which is taken from that patent application and comprise one or more discs 12 mounted on a hub 25 for rotation by a spindle motor 27 mounted to a baseplate 15, in a manner well known in the art. The discs are accessed using a transducer head 10 mounted on a flexure 20 attached to a movable actuator. The transducer is repeatably positioned relative to any one of the tracks under the action of a stepper motor 30 which is coupled to the actuator arms 32, 20 through a flexible band 38 which winds and unwinds on the stepper motor shaft 36 with rotation of the stepper motor 30.

The electronics which are normally incorporated in a disc drive of this type are shown at the top of FIG 1A. These electronics include a microprocessor 40 which provides the positioning commands to a stepper motor sequencer 42 which enables the stepper motor power drivers 44 which provide power to various selected phases of a stepper motor 30. The spindle motor 27 is being driven in constant rotation by the spindle motor controller 46.

When DC power is removed from the disc drive, an alarm signal "-DC UNSAFE" which is the output of the power fault monitor 48 (typically standard part of a disc drive) goes true. This disables the normal stepper motor control circuitry 40, 42, 44 and enables the stepper motor retract sequencer 50 and the stepper motor retract power driver 52. Details of the sequencer 50 are shown in FIG 3 and of the retract power driver are shown in FIG 4. These will be discussed in some detail below.

The spindle motor back EMF power source 54, details of which are shown in FIG 2, is provided because by definition DC power from the normal power source is not available. The stepper retract circuitry of this invention therefore uses the back EMF from the still spinning spindle motor 27 to power the stepper retract circuits. This back EMF is sufficient to drive the circuitry for from three to

five seconds after DC power is removed because of the momentum of the spinning discs. Therefore, a back EMF voltage can be taken from the spindle motor windings and applied to the rectification circuit 60 shown in FIG 2.

The output of this circuit comprises a rectified and filtered power signal which is applied on line 62 to the retract sequencer 50 of Figure 3. The signal from one of the three spindle motor windings is connected directly through to the sequencer 53 on line 64.

This signal on line 64 is applied to the circuit 66 in the lower left-hand portion of Figure 3; this circuit comprises two transistors 67, 68 which convert this analogue wave form from the spindle motor to the necessary digital clock signal which goes out on line 70 to clock the flipflops 80, 82, 84 on the upper right of FIG 3.

At the upper left of FIG 3 appears a transistor switch 72 including a pair of transistors 74, 76 whose state is controlled by the DC UNSAFE signal on line 49 from the power fault monitor 48. A change in state of the "DC UNSAFE" signal which is indicated by the unsafe signal going low allows the rectified and filtered back EMF on line 62 to power the sequencer and the retract motor power driver on line 78.

The sequence in which the selected phases of the stepper motor 30 are enabled is determined by the logic elements comprising the flipflops 80, 82, 84 and associated circuits shown on the right side of FIG 3. It is the change in state of these three flipflops as timed by the clock signal on line 70 that shifts the enabling signals from one phase to another of the motor. The sequence is fixed to drive the carriage to the fixed, "park" position at the inner diameter of the disc. To minimize component count, it has been determined that in the disclosed embodiment, only three stepper motor phases need to be used to perform the parking operation. These three phases are represented on the right-hand side of FIG 4, the retract power driver 52. It can be seen that one of the two ends of a winding incorporated in each phase is coupled to the power signal which is established by the rectified and filtered back EMF and provided on line 78. Therefore, one end of each of these windings is constantly driven in a unipolar manner by conventional transistors 86, 88, 90. The motor phase enabled at any given time is defined by the phase enable lines 92, 94, 96, whose state is defined by the sequencing logic shown on the right side of Fig. 3.

As the clock signals are created on line 70, the logic is set up so that when the clock is running, the sequencer produces a sequence of signals as shown in FIG 5B which appear on the respective control lines 92, 94, 96. The sequence repeats every five clock cycles. The resulting sequence of holding torque vectors given by driving an exemplary 10-phase stepper motor in this manner is shown in FIG 5A.

In summary, by driving only three phases of the stepper motor, and using the momentum of the spindle motor (which continues to spin after DC power is eliminated) as both a power source and a clock source by tapping the back EMF off one winding for the clock source and off a plurality of windings for the power source, power down stepper retract circuitry can be provided. This circuitry is enabled only when power is removed from the disc drive. It economically positions the read/write transducer heads in a landing zone at the inner diameter of the discs and thereby protects the recorded data. This also reduces the starting torque requirements which the motor must meet.

Other features and advantages of this invention may become apparent to a person of skill in the art who studies the subject invention disclosure. Therefore, the scope of this invention is to be limited only by the following claims.

Claims

1. A disc drive comprising:

at least one storage disc (12) mounted for rotation within a disc drive housing;

a spindle motor (27) for driving said disc in rotation;

an actuator for reciprocally driving a transducer array (10) relative to the disc, said actuator including a carriage for said transducer array;

a motor (30) drivingly connected to the carriage for positioning the carriage and transducer array relative to the disc; and

a circuitry (48, 50, 52) for detecting removal of power and for parking the transducer array at a defined park position relative to the disc after power is removed from the drive utilising power generated by the spindle motor (27), characterised in that:

said carriage motor is a stepper motor, and said circuitry comprises a retract sequencer circuit (50) including a power circuit (72) coupled between the spindle motor (27) and selected windings of the actuator stepper motor (30), and a clock circuit (66) responsive to an output of a winding of the spindle motor (27), both power and clock circuits being activated by removal of power to the spindle motor to energise said selected windings of the stepper motor to step said stepper motor a number of steps necessary to park said transducer array at said defined position.

2. A disc drive as claimed in claim 1, charac-

terised in that the circuitry (48) responsive to removal of power from said disc drive activates said sequencer circuit.

3. A disc drive as claimed in claim 1 or claim 2, characterised in that said spindle motor (27) generates a back EMF when DC power to the drive is removed, said stepper motor retract sequencer circuit (50) comprising means (52) for coupling said generated back EMF to selected phases of said stepper motor (30) to cause said stepper motor to move said transducer array (10) to said park position, the circuitry (48) responsive to removal of power from said disc drive activating said sequencer circuit.

4. A disc drive as claimed in claim 3, characterised in that said sequencer circuit includes coupling means (54) for rectifying and filtering said back EMF and coupling said back EMF to the windings of said stepper motor (30).

5. A disc drive as claimed in claim 4, characterised in that outputs of said coupling means (52) of said sequencer circuit are connected to one end of said windings of said stepper motor, said sequencer circuit further including a clock circuit (66) responsive to an output of a winding of said spindle motor (27) to generate a sequence of clock pulses, the output of said clock circuit being coupled to the other end of said windings to energise said windings.

6. A disc drive as claimed in claim 4 or claim 5, characterised in that said generated back EMF and the output of said clock circuit (66) are coupled to at least two windings of said stepper motor (30).

7. A disc drive as claimed in any of claims 1 to 6 having an external DC power supply to said disc drive motor (27), means (48) for generating a signal indicating the presence of said DC power supply, said sequencer circuit (50, 52) being responsive to said signal generating means to initiate actuator movement to the defined park position, said defined position being generally at the inner portion of said discs (12) and inside the diameter of the innermost data track.

8. A disc drive as claimed in claim 7, characterised in that said sequencer circuit (50, 52) is responsive to a change in state of an output of said signal generating means to initiate the defined movement of said actuator.

Revendications

1. Unité de disques comportant :

au moins un disque (12) de stockage monté de façon à tourner à l'intérieur d'une enceinte d'unité de disques ;

un moteur (27) de broche destiné à entraîner ledit disque en rotation ;

un actionneur destiné à animer d'un mouvement alternatif un ensemble transducteur (10) par rapport au disque, ledit actionneur comprenant un chariot pour ledit ensemble transducteur ;

un moteur (30) relié en prise d'entraînement au chariot pour positionner le chariot et l'ensemble transducteur par rapport au disque ; et

un ensemble de circuits (48, 50, 52) destiné à détecter la suppression d'énergie et à immobiliser l'ensemble transducteur dans une position d'immobilisation définie par rapport au disque après que l'énergie a été supprimée de l'entraînement utilisant la puissance générée par le moteur de broche (27), caractérisée en ce que :

ledit moteur de chariot est un moteur pas à pas, et ledit ensemble de circuits comporte un circuit séquenceur de retrait (50) comprenant un circuit de puissance (72) couplé entre le moteur de broche (27) et des bobinages choisis du moteur pas à pas (30) de l'actionneur, et un circuit d'horloge (66) sensible à un signal de sortie d'un bobinage du moteur de broche (27), les circuits de puissance et d'horloge étant tous deux activés par la suppression de l'énergie fournie au moteur de broche pour exciter lesdits bobinages choisis du moteur pas à pas afin de faire progresser ledit moteur pas à pas d'un nombre de pas nécessaire pour immobiliser ledit ensemble transducteur dans ladite position définie.

2. Unité de disques selon la revendication 1, caractérisée en ce que l'ensemble de circuits (48) sensible à la suppression d'énergie de ladite unité de disques active ledit circuit séquenceur.

3. Unité de disques selon la revendication 1 ou la revendication 2, caractérisée en ce que ledit moteur de broche (27) génère une force contre-électromotrice lorsque l'énergie à courant continu de l'unité est supprimée, ledit circuit séquenceur de retrait (50) du moteur pas à pas comportant un moyen (52) destiné à coupler ladite force contre-électromotrice générée à des phases choisies dudit moteur pas à pas (30) pour amener ledit moteur pas à pas

à déplacer ledit ensemble transducteur (10) jusqu'à ladite position d'immobilisation, l'ensemble de circuits (48) réagissant à la suppression d'énergie de ladite unité de disques en activant ledit circuit séquenceur.

4. Unité de disques selon la revendication 3, caractérisée en ce que ledit circuit séquenceur comporte un moyen de couplage (54) destiné à redresser et filtrer ladite force contre-électromotrice et à coupler ladite force contre-électromotrice aux bobinages dudit moteur pas à pas (30).

5. Unité de disques selon la revendication 4, caractérisée en ce que des sorties dudit moyen de couplage (52) dudit circuit séquenceur sont connectées à une extrémité desdits bobinages dudit moteur pas à pas, ledit circuit séquenceur comprenant en outre un circuit d'horloge (66) qui, en réponse à un signal de sortie d'un bobinage dudit moteur de broche (27), génère une séquence d'impulsions d'horloge, la sortie dudit circuit d'horloge étant couplée à l'autre extrémité desdits bobinages pour exciter lesdits bobinages.

6. Unité de disques selon la revendication 4 ou la revendication 5, caractérisée en ce que ladite force contre-électromotrice générée et la sortie dudit circuit d'horloge (66) sont couplées à au moins deux bobinages dudit moteur pas à pas (30).

7. Unité de disques selon l'une quelconque des revendications 1 à 6, comportant une alimentation extérieure en énergie continue pour ledit moteur (27) d'entraînement de disque, un moyen (48) destiné à générer un signal indiquant la présence de ladite alimentation en énergie continue, ledit circuit séquenceur (50, 52) réagissant audit moyen de génération de signal en déclenchant un mouvement d'actionneur vers la position d'immobilisation définie, ladite position définie étant généralement à la partie intérieure desdits disques (12) et à l'intérieur du diamètre de la piste de données située le plus à l'intérieur.

8. Unité de disques selon la revendication 7, caractérisée en ce que ledit circuit séquenceur (50, 52) réagit à un changement d'état d'un signal de sortie dudit moyen de génération de signal en déclenchant le mouvement défini dudit actionneur.

Patentansprüche

1. Plattenantrieb
   - mit wenigstens einer Speicherplatte (12), die für eine Rotation in einem Plattenantriebsgehäuse angeordnet ist,
   - mit einem Spindelmotor (27) für den Drehantrieb der Platte,
   - mit einer Betätigungseinrichtung für den Hin- und Herantrieb einer Wandleranordnung (10) relativ zu der Platte, wobei die Betätigungseinrichtung einen Schlitten für die Wandleranordnung aufweist,
   - mit einem Motor (30), der für einen Antrieb mit dem Schlitten verbunden ist, um den Schlitten und die Wandleranordnung relativ zu der Platte zu positionieren, und
   - mit einer Schaltungsanordnung (48, 50, 52) zum Feststellen der Leistungswegnahme und zum Parken der Wandleranordnung in einer definierten Parkposition bezüglich dem Platte, nachdem die Leistung von dem Antrieb weggenommen ist, wobei Leistung verwendet wird, die von dem Spindelmotor (27) erzeugt wird, dadurch gekennzeichnet, daß
   - der Schlittenmotor ein Schrittmotor ist und die Schaltungsanordnung eine Rückziehfolgesteuerschaltung (50) mit einer Leistungsschaltung (72), die zwischen den Spindelmotor (72) und ausgewählte Wicklungen des Betätigungseinrichtungs-Schrittmotors (30) geschaltet ist, und eine Taktschaltung (66) aufweist, die auf ein Ausgangssignal einer Wicklung des Spindelmotors (27) anspricht, wobei sowohl die Leistungs- als auch die Taktschaltung durch Wegnahme der Leistung an dem Spindelmotor aktiviert wird, um die ausgewählten Windungen des Schrittmotors zu erregen, damit der Schrittmotor eine Anzahl von Schritten macht, die erforderlich sind, um die Wandleranordnung in der definierten Position zu parken.

2. Plattenantrieb nach Anspruch 1, dadurch gekennzeichnet, daß die Schaltungsanordnung (48), die auf die Wegnahme der Leistung von dem Plattenantrieb anspricht, die Folgesteuerschaltung aktiviert.

3. Plattenantrieb nach Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß der Spindelmotor (27) eine Gegen-EMK erzeugt, wenn die Gleichstromspeisung für den Antrieb weggenommen ist, wobei die Schrittmoter-Rückziehfolgesteuerschaltung (50) Einrichtungen (52) zum Koppeln der erzeugten Gegen-EMK mit ausgewählten Phasen des Schrittmotors (30)

aufweist, um den Schrittmotor zu veranlassen, die Wandleranordnung in die Parkposition zu bewegen, und die Schaltungsanordnung (48), die auf die Wegnahme der Leistung von dem Plattenantrieb anspricht, die Folgesteuerschaltung aktiviert.

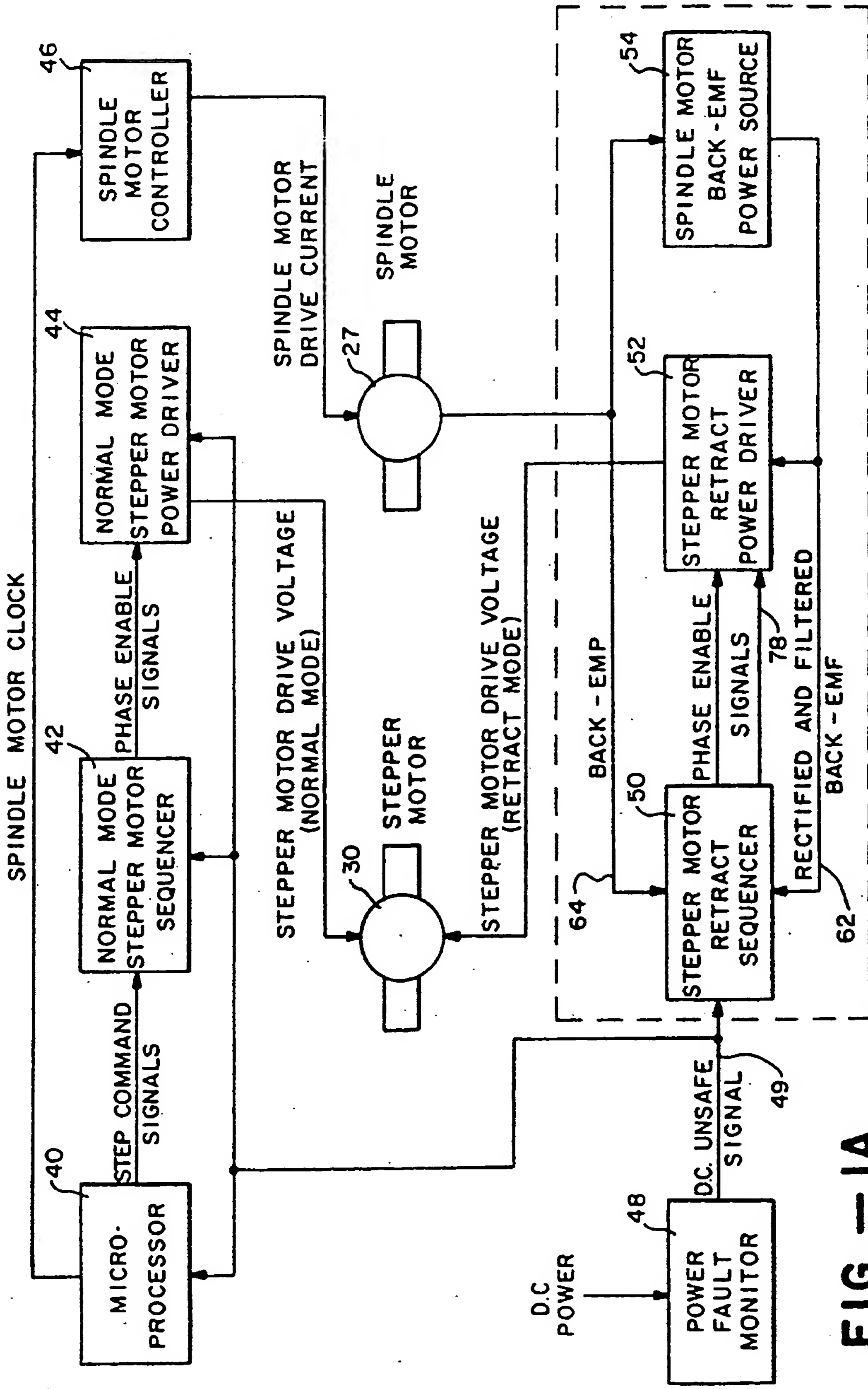
4. Plattenantrieb nach Anspruch 3, dadurch gekennzeichnet, daß die Folgesteuerschaltung eine Koppelungseinrichtung (54) zum Gleichrichten und Filtern der Gegen-EMK und zum Koppeln der Gegen-EMK mit den Wicklungen des Schrittmotors (30) aufweist.

5. Plattenantrieb nach Anspruch 4, dadurch gekennzeichnet, daß die Ausgangssignale der Koppelungseinrichtungen (52) der Folgesteuerschaltung mit einem Ende der Wicklungen des Schrittmotors verbunden sind, und daß die Folgestauerschaltung weiterhin eine Taktschaltung (66) aufweist, die auf ein Ausgangssignal einer Wicklung des Spindelmotors (27) anspricht, um eine Folge von Taktimpulsen zu erzeugen, wobei das Ausgangssignal der Taktschaltung mit dem anderen Ende der Wicklungen gekoppelt ist, um die Wicklungen zu erregen.

6. Plattenantrieb nach Anspruch 4 oder Anspruch 5, dadurch gekennzeichnet, daß die erzeugte Gegen-EMK und das Ausgangssignal der Taktschaltung (66) mit wenigstens zwei Wicklungen des Schrittmotors (30) gekoppelt sind.

7. Plattenantrieb nach einem der Ansprüche 1 bis 6, welcher eine externe Gleichstromspeisung für den Plattenantriebsmotor (27) und Einrichtungen (48) zum Erzeugen eines Signals aufweist, das das Vorhandensein der Gleichstromspeisung anzeigt, wobei die Folgesteuerschaltung (50, 52) auf die signalerzeugenden Einrichtungen anspricht, um die Betätigungseinrichtungsbewegung in die definierte Parkposition einzuleiten, wobei die definierte Position insgesamt an dem inneren Abschnitt der Platten (12) und innerhalb des Durchmessers der innersten Datenspur liegt.

8. Plattenantrieb nach Anspruch 7, dadurch gekennzeichnet, daß die Folgesteuerschaltung (50, 52) auf eine Zustandsänderung einem Ausgangssignals der signalerzeugenden Einrichtungen anspricht, um die definierte Bewegung der Betätigungseinrichtung einzuleiten.



MICRO-PROCESSOR
40
STEP COMMAND SIGNALS
NORMAL MODE STEPPER MOTOR SEQUENCER
42
PHASE ENABLE SIGNALS
NORMAL MODE STEPPER MOTOR POWER DRIVER
44
SPINDLE MOTOR CONTROLLER
46
SPINDLE MOTOR CLOCK
SPINDLE MOTOR DRIVE CURRENT
SPINDLE MOTOR
27
STEPPER MOTOR DRIVE VOLTAGE (NORMAL MODE)
STEPPER MOTOR
30
STEPPER MOTOR DRIVE VOLTAGE (RETRACT MODE)
D.C POWER
POWER FAULT MONITOR
48
D.C. UNSAFE SIGNAL
49
STEPPER MOTOR RETRACT SEQUENCER
50
64
BACK - EMP
PHASE ENABLE SIGNALS
78
RECTIFIED AND FILTERED BACK - EMF
62
STEPPER MOTOR RETRACT POWER DRIVER
52
SPINDLE MOTOR BACK - EMF POWER SOURCE
54

FIG. — IA

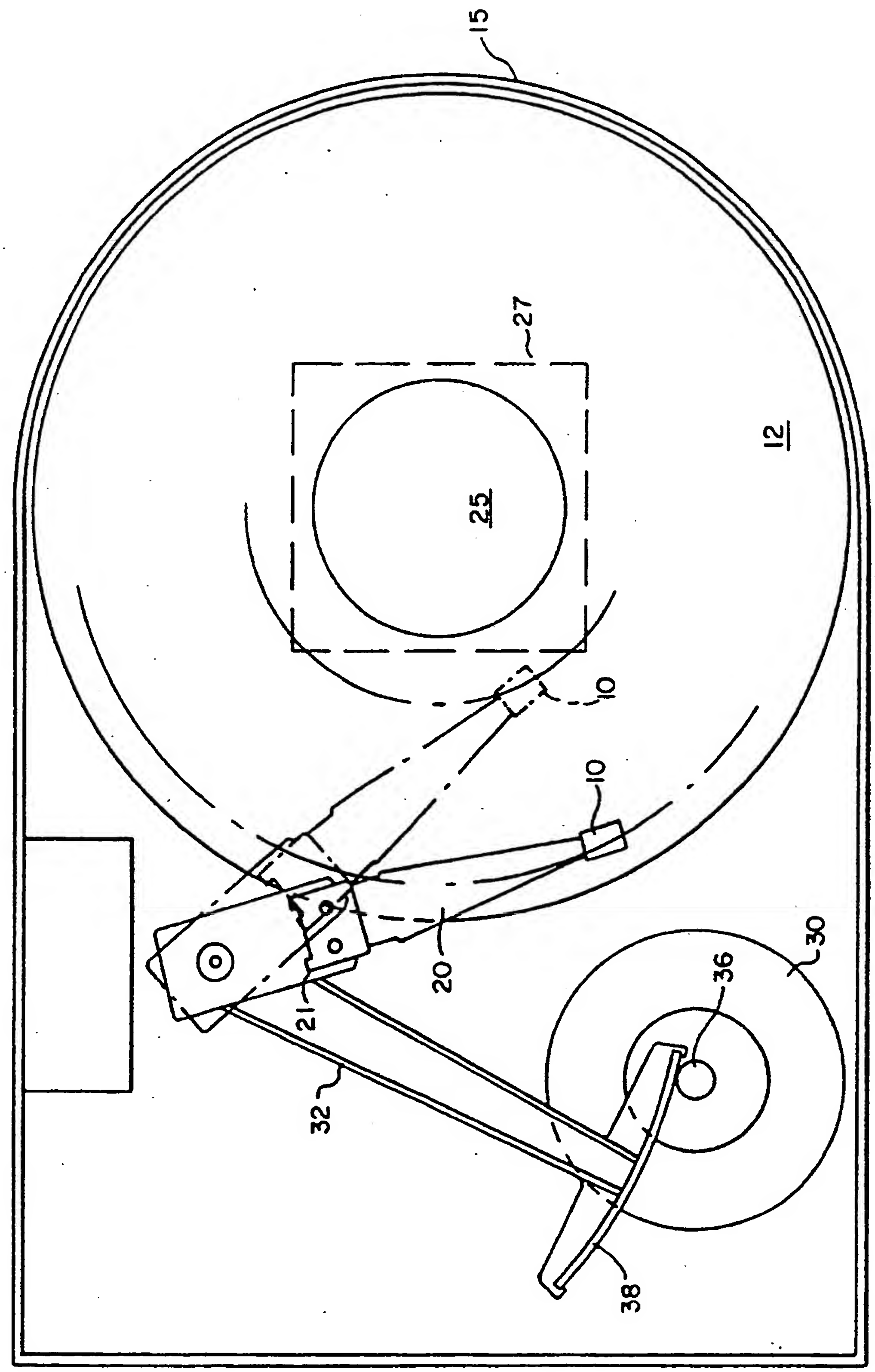


FIG.—1B

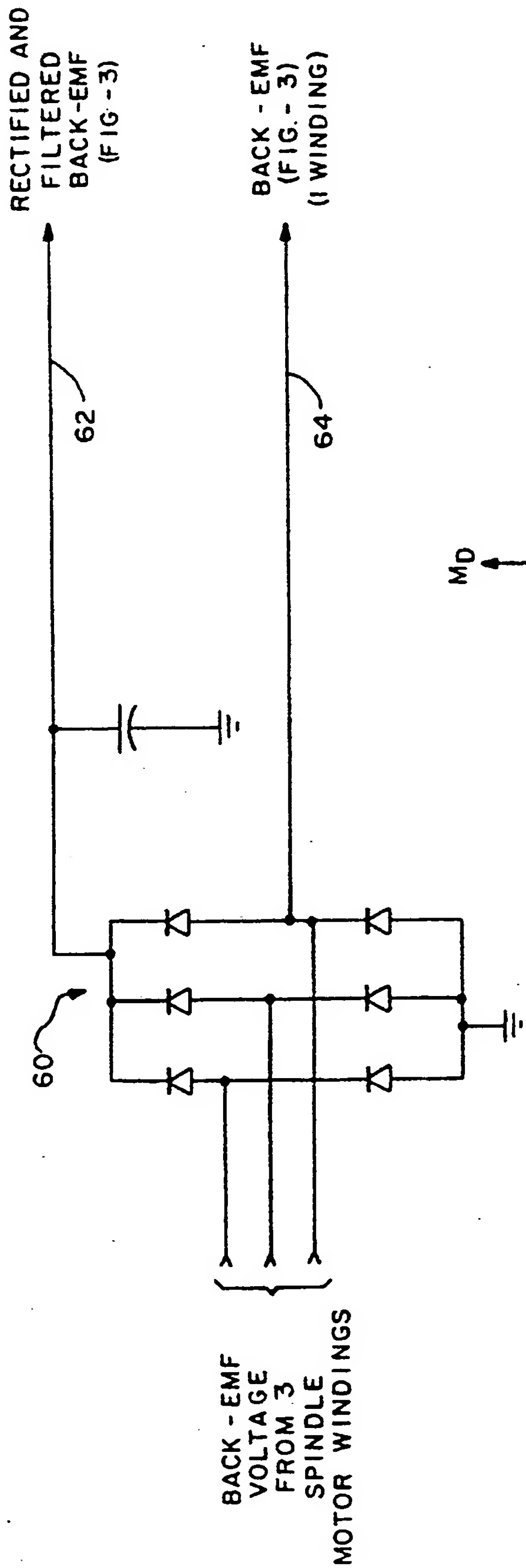

RECTIFIED AND FILTERED BACK-EMF (FIG-3)
BACK - EMF (FIG.- 3) (1 WINDING)
62
64
60
BACK - EMF VOLTAGE FROM 3 SPINDLE MOTOR WINDINGS

FIG.—2

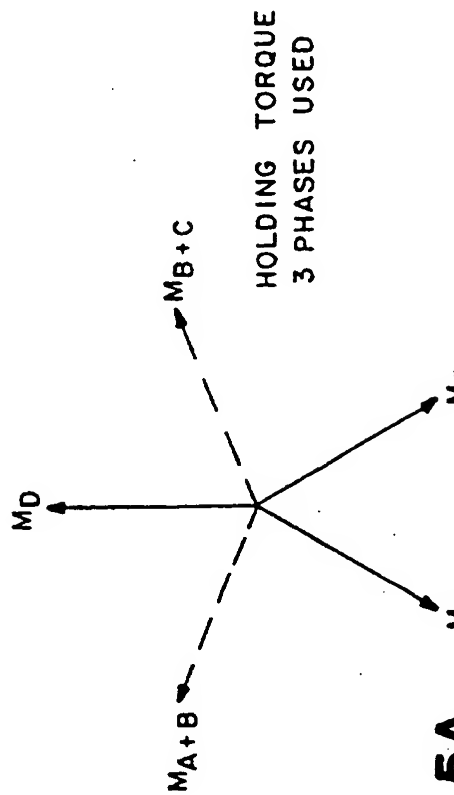

HOLDING TORQUE 3 PHASES USED
M_{B+C}
M_C
M_D
M_A
M_{A+B}

FIG.—5A

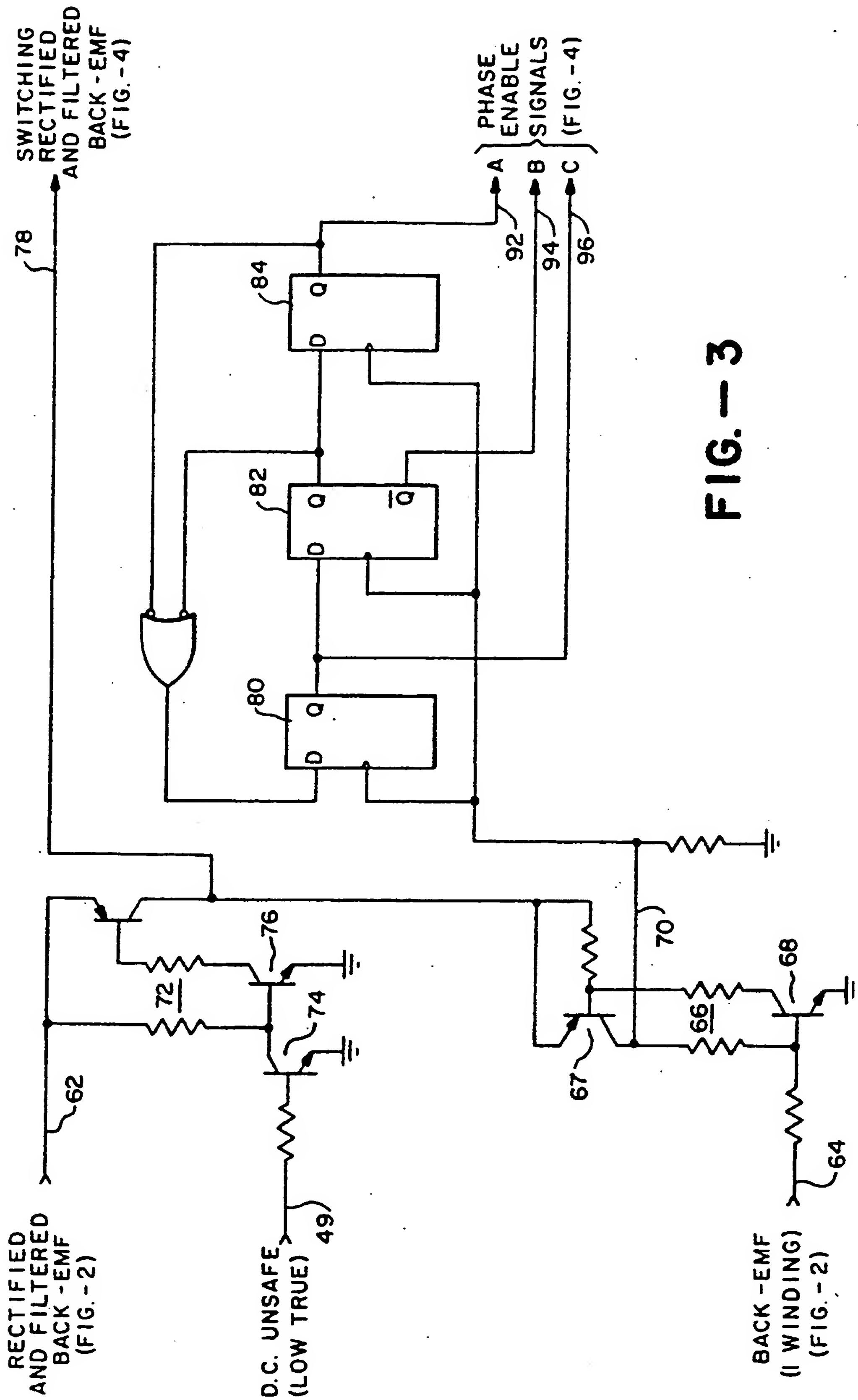

SWITCHING RECTIFIED AND FILTERED BACK-EMF (FIG.-4)
78
PHASE ENABLE SIGNALS (FIG.-4)
A
B
C
92
94
96
84
82
80
D
Q
D
Q
Q̄
D
Q
62
72
76
74
49
70
68
66
67
64
RECTIFIED AND FILTERED BACK-EMF (FIG.-2)
D.C. UNSAFE (LOW TRUE)
BACK-EMF (I WINDING) (FIG.-2)

FIG. — 3

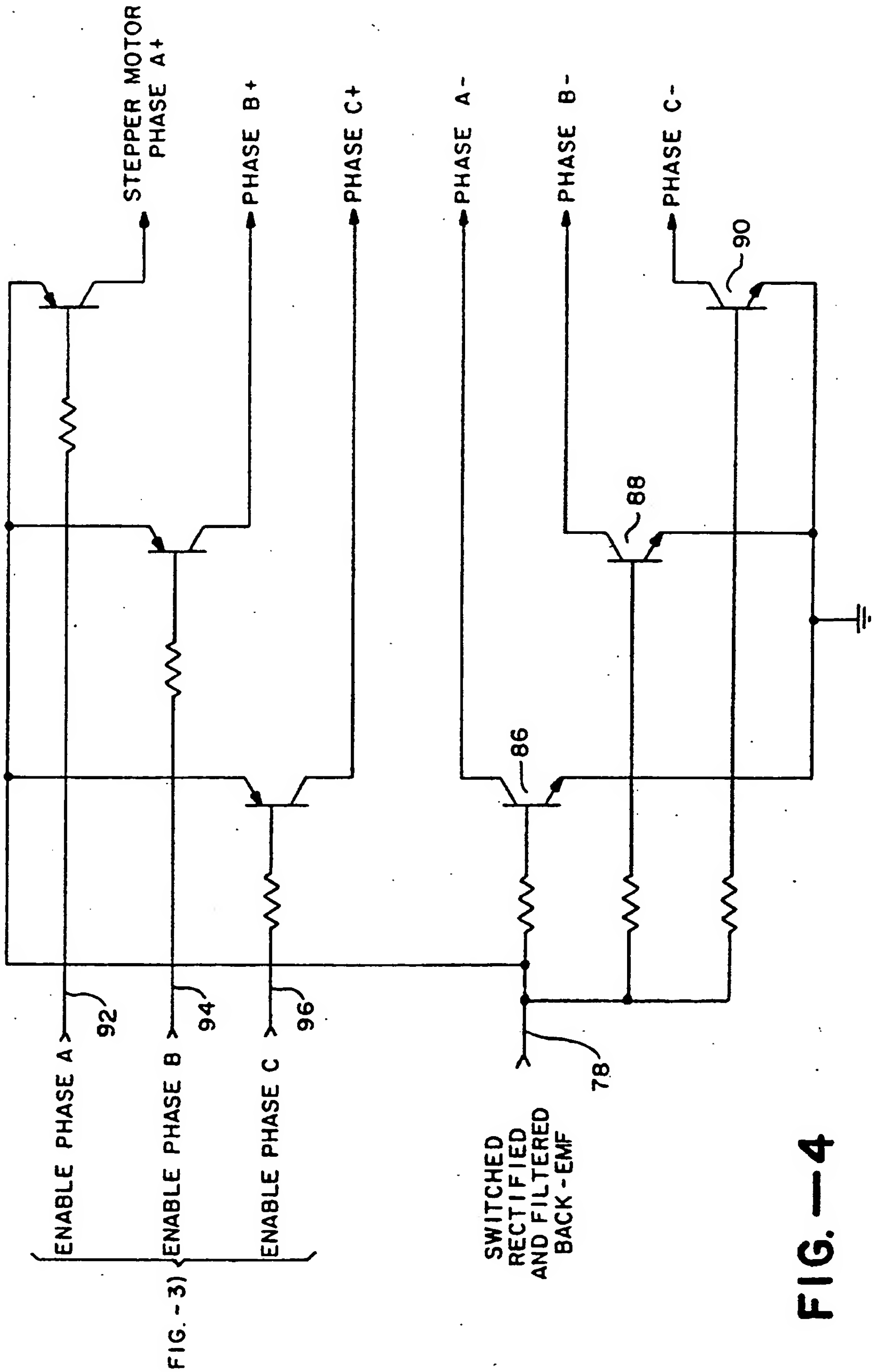

STEPPER MOTOR PHASE A+
PHASE B+
PHASE C+
PHASE A-
PHASE B-
PHASE C-
90
88
86
92
94
96
78
ENABLE PHASE A
ENABLE PHASE B
ENABLE PHASE C
(FIG. - 3)
SWITCHED RECTIFIED AND FILTERED BACK-EMF

FIG. — 4

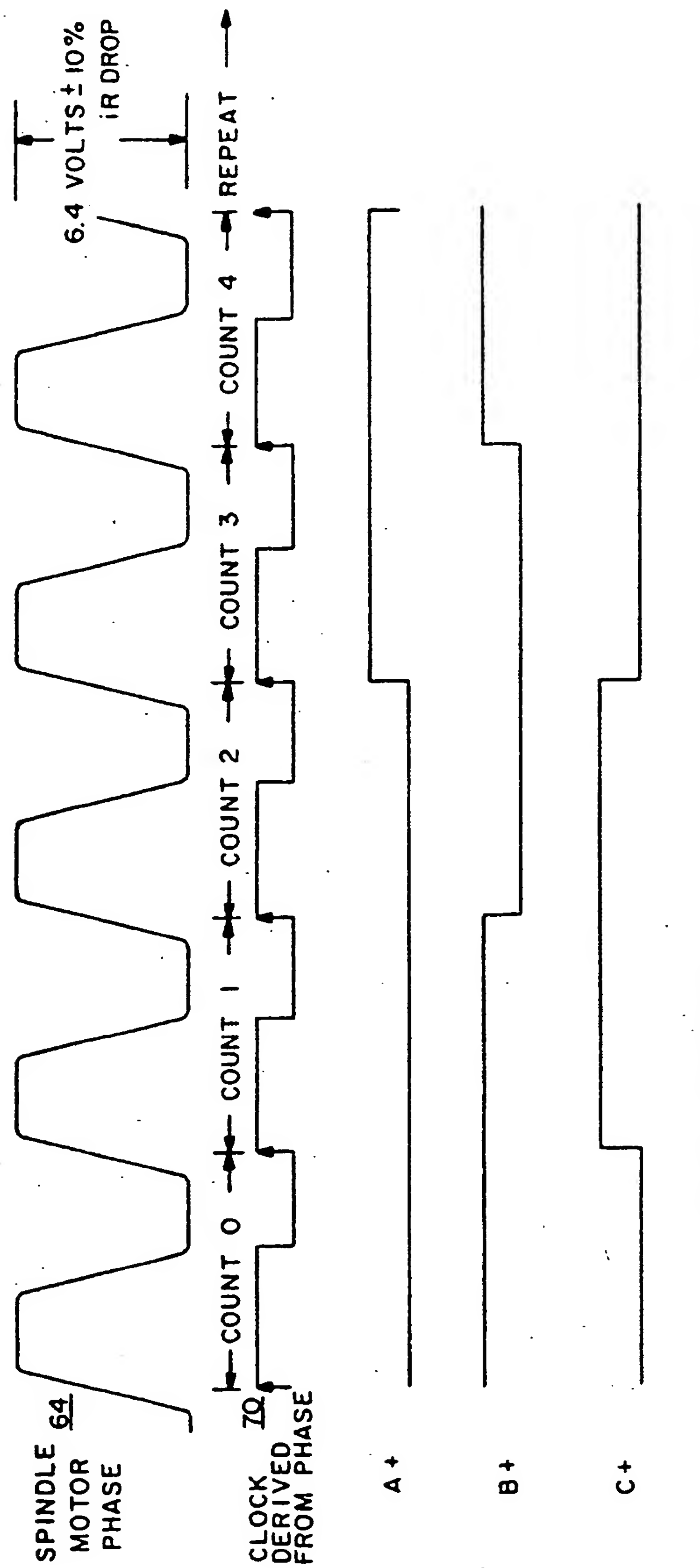


FIG. — 5B

COUNT	SEQUENCE A	B	C
0	L	H	L
1	L	H	H
2	L	L	H
3	H	L	L
4	H	H	L